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REVISION OF ISO 3010 "BASES FOR DESIGN OF STRUCTURES – SEISMIC ACTIONS ON STRUCTURES"

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Abstract

The first edition of International Standard ISO 3010 "Bases for design of structures - Seismic actions on structures" was published in 1988 and the second edition was published in 2001 through the activity of the working group in ISO/TC 98. The final draft for the third edition ISO/DIS:2016 is under final review among member countries and will be hopefully published as the International Standard by the end of 2016. TC 98 deals with "Bases for design of structures." The aim of TC 98 is to create a coherent design system of International Standards in the field of building and civil engineering works. The system forms a basis for regional and national standard bodies which prepare their standards for particular types of structures and structural materials. ISO/DIS,i.e. the final draft for the third edition, has 11 clauses in the normative text and 16 informative annexes. The text of ISO 3010/DIS includes principles for the determination of seismic actions on structures and seismic design. The text does not give any specific values for factors to determine seismic loadings. The new clause of the text is 10 Non-linear static analysis. The annexes give useful information to determine the values for those factors, and new annexes are I Non-linear static analysis and capacity spectrum method, J Soil-structure interaction, K Seismic design of high-rise buildings, L Deformation limits, N Non-engineered construction, and O Tsunami actions. ISO 3010 includes almost all items and factors to be considered. Therefore it is a useful document for establishing a new code or revising an old one. These features of ISO 3010 remain the same in the draft for the third edition.

Keywords: ISO; seismic code; seismic actions; equivalent static analysis; dynamic analysis

1. Introduction

The first edition of International Standard ISO 3010 "Bases for design of structures - Seismic actions on structures" [1] was published in 1988 and the second edition[2] was published in 2001 through the activity of the working group in ISO/TC 98. TC 98 deals with "Bases for design of structures." The aim of TC 98 is to create a coherent design system of International Standards in the field of building and civil engineering works. The system forms a basis for regional and national standard bodies which prepare their standards for particular types of structures and structural materials. ISO 3010 includes principles for the determination of seismic actions on structures and seismic design. Since it does not give any specific values for factors to determine seismic loadings, it is not possible to design a structure only according to ISO 3010. Its annexes, however, give useful information to determine the values for those factors. ISO 3010 includes almost all items and factors to be considered. Therefore it is a useful document for establishing a new code or revising an old one. These features of ISO 3010 remain the same in the revision for the third edition. This paper introduces the activities of TC 98 and the ISO/DIS 3010:2016[3], i.e. the draft for the third edition.

2. ISO/TC 98 "Bases for Design of Structures"

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies. The work of preparing International Standards is normally carried out through ISO technical committees (TC's). Each TC has several sub-committees (SC's) and each SC usually has several working groups (WG's). Currently there are approximately 240 TC's, 520 SC's and 2,600 WG's in ISO.

ISO/TC 98 is one of the TC's which deals with "Bases for design of structures". The aim of TC 98 is to create a coherent design system of International Standards in the field of building and civil engineering works. The system forms a basis for regional and national standard bodies that prepare their standards for particular types of structures and structural materials. Since TC 98 was established in 1961, its secretariat has been in the Polish Committee for Standardization. In TC 98 there are 24 participating members and 36 observers (one member or one observer from each country). TC 98 has three main tasks that are shared among three SC's; (1) terminology and symbols, (2) reliability of structures, and (3) loads, forces and other actions on structures [4].

2.1 SC 1 - Terminology and symbols

SC 1 deals with the definitions and explanations of the terms used in the standards and other documents which are prepared by TC 98, since very often the meanings of certain terms are different from their meanings in everyday language. The terms need to be well understood and correctly used without ambiguity. Also, similar terms have slightly different meanings in different languages. The task of establishing a coherent terminology system is essentially important. SC 1 is concerned in symbols and their subscripts and superscripts as well.

2.2 SC 2 - Reliability of structures

The reliability of structures is understood as a combination of their safety and serviceability. These are verified in two separate groups of limit states, i.e. (1) ultimate limit state and (2) serviceability limit state. In both limit states, all parameters such as loads, material properties, structural dimensions, etc. are considered as random variables. Because complete knowledge of statistical distributions of these parameters is lacking, the randomness is considered by a system of partial factors.
SC 2 is responsible for ISO 2394 "General principles on reliability of structures" [5]. ISO 2394, sometimes called the bible of TC 98, introduces fundamental methods for verifying the reliability of structures and is the normative reference to ISO 3010.

2.3 SC 3 - Loads, forces and other actions on structures

SC 3 elaborates the bases for various categories of loads, e.g. loads due to service loads in various types of buildings, forces caused by wind and by snow on roofs. Since 2001, SC 3 has been dealing with seismic actions, which had been dealt with by WG 1 which had belonged directly to TC 98. As to seismic actions, SC 3 has three international standards, i.e. ISO 3010 ”Bases for design of structures - Seismic actions on structures”[2], ISO 23469, “Seismic actions for designing geotechnical works”[6] and ISO 13033 “Bases for design of structures - Loads, forces and other actions - Seismic actions on nonstructural components for building applications”[7]. The values of these actions are given only in relatively large limits, because conditions vary considerably between countries. However, the bases for treatment of the actual data and methods of their measurement can be standardized.

3. Revision for the third edition of ISO 3010

The first edition of ISO 3010 was elaborated in WG 1 under TC 98. The convener was Professor Yutaka Osawa of the University of Tokyo, who was succeeded by Professor Yutaka Matsushima of the University of Tsukuba. Since the revision for the second edition started in 1995, the convener has been Yuji Ishiyama, one of the co-authors of this paper.

The standards prepared by TC 98 serve as references in the field of building and civil engineering works, and are frequently called “Code for Code Writers”. They are also expected to serve as guidelines for issues during construction. As for ISO 3010, it includes only principles for the determination of seismic actions and seismic design. It does not give any specific values for factors to determine design seismic forces. Therefore it is not possible to determine seismic loads or to design a structure only according to ISO 3010. The annexes of ISO 3010, however, give information to determine those values.

ISO 3010 includes almost all items and factors to be considered. Therefore it is a useful document for establishing a new code or revising an old one. These features of the standard remain the same in ISO/DIS 3010 for the third edition. The revision of the text is rather minor, but the annexes are extensively modified to include the current knowledge on earthquake engineering. ISO/DIS 3010 consists of 11 clauses and 16 informative annexes.

The 11 clauses are 1 Scope, 2 Normative references, 3 Terms and definitions, 4 Symbols and abbreviated terms, 5 Bases of seismic design, 6 Princiles of seismic design, 7 Principles of evaluating seismic actions, 8 Evaluation of seismic actions by equivalent static analysis, 9 Evaluation of seismic actions by dynamic analysis, 10 Non-linear static analysis, and 11 Estimation of paraseismic influences. Clause 10 is newly added.

The 16 annexes are A Load factors as related to the reliability of the structure, seismic hazard zoning factor and representative values of earthquake ground motion intensity, B Normalized design response spectrum, C Seismic force distribution parameters for equivalent static analysis, D Structural design factor for linear analysis, E Combination of components of seismic action, F Torsional moments, G Damping ratio, H Dynamic analysis, I Non-linear static analysis and capacity spectrum method, J Soil-structure interaction, K Seismic design of high-rise buildings, L Deformation limits, M Response control systems, N Non-engineered construction, O Tsunami actions, and P Paraseismic influences. New annexes are I, J, K, L, N and O.

4. Evaluation of seismic actions by equivalent static analysis

The evaluation of seismic actions by equivalent static analysis in Clause 8 can be summarized as follows:

In the seismic analysis of structures based on a method using equivalent static loadings, the variable seismic actions for ULS ans for SLS may be evaluated as follows.

4.1 Ultimate limit state (ULS)

The design lateral seismic force of the *i* th level of a structure for ULS, $F_{\mathrm{E,u},i}$, may be determined by

$$F_{\mathrm{E,u},i} = \gamma_{\mathrm{E,u}}\, k_{\mathrm{Z}}\, k_{\mathrm{E,u}}\, k_{\mathrm{S}}\, k_{\mathrm{D}}\, k_{\mathrm{R}}\, k_{\mathrm{F},i} \sum_{j=1}^{n} F_{\mathrm{G},j} \tag{1}$$

or the design lateral seismic shear for ULS, $V_{\mathrm{E,u},i}$, may be used instead of the above seismic force

$$V_{\mathrm{E,u},i} = \gamma_{\mathrm{E,u}}\, k_{\mathrm{Z}}\, k_{\mathrm{E,u}}\, k_{\mathrm{S}}\, k_{\mathrm{D}}\, k_{\mathrm{R}}\, k_{\mathrm{V},i} \sum_{j=i}^{n} F_{\mathrm{G},j} \tag{2}$$

where,

$\gamma_{E,u}$ is the load factor as related to the reliability of the structure for ULS;

k_Z is the seismic hazard zoning factor to be specified in the national code or other national documents;

$k_{E,u}$ is the representative value of earthquake ground motion intensity for ULS to be specified in the national codes or other national documents considering the seismicity;

k_S is the ratio of the earthquake gorund motion intensity considering the effect of soil conditions to the earthquake ground motion intensity for the reference site condition (new factor for the third edition[8]);

k_D is the structural design factor to be specified for various structural systems according to their ductility, acceptable deformation, restoring force characteristics, and overstrength;

k_R is the ordinate of the normalized design response spectrum, as a function of the fundamental natural period of the structure considering the effect of soil conditions and damping property of the structure;

$k_{F,i}$ is the seismic force distribution factor of the i th level to distribute the seismic base shear to each level, which characterizes the distribution of seismic forces in elevation, where $k_{F,i}$ satisfies the condition $\sum k_{\mathrm{F},i} = 1$;

$k_{V,i}$ is the seismic shear distribution factor of the i th level which is the ratio of the seismic shear factor of the i th level to the seismic shear factor of the base, and characterizes the distribution of seismic shears in elevation, where $k_{V,i} = 1$ at the base and usually becomes largest at the top;

$F_{G,j}$ is the gravity load at the j th level of the structure;

n is the number of levels above the base.

4.2 Serviceability limit state (SLS)

The design lateral seismic force of the i th level of a structure for SLS, $F_{\mathrm{E,s},i}$, may be determined by:

$$F_{\mathrm{E,s},i} = \gamma_{\mathrm{E,s}}\, k_{\mathrm{Z}}\, k_{\mathrm{E,s}}\, k_{\mathrm{S}}\, k_{\mathrm{R}}\, k_{\mathrm{F},i} \sum_{j=1}^{n} F_{\mathrm{G},j} \tag{3}$$

or the design lateral seismic shear for SLS, $V_{\mathrm{E,s},i}$, may be used instead of the above seismic force,

$$V_{\mathrm{E,s},i} = \gamma_{\mathrm{E,s}}\, k_{\mathrm{Z}}\, k_{\mathrm{E,s}}\, k_{\mathrm{S}}\, k_{\mathrm{R}}\, k_{\mathrm{V},i} \sum_{j=i}^{n} F_{\mathrm{G},j} \tag{4}$$

where,

$\gamma_{E,s}$ is the load factor as related to reliability of the structure for SLS;

$k_{E,s}$ is the representative value of earthquake ground motion intensity for SLS to be specified in the national code or other national documents by considering the seismicity.

$k_{E,u}$ and $k_{E,s}$ (see Table 1) may be replaced by a unique representative k_E (see Table 2) as specified in ISO 2394 in the verification procedure, by which the reliability of the structure and the consequences of failure, including the significance of the type of failure, are taken into account to specify the load factors $\gamma_{E,u}$ and $\gamma_{E,s}$.

5. Annexes related to the equivalent static analysis

Specific values for various factors are not given in the text. The annexes, however, describe informatively the factors as follows (equation, table and figure numbers are not the same as ISO/DIS 3010.

5.1 Load factors and representative values of earthquake ground motion intensity

The load factors $\gamma_{E,u}$ and $\gamma_{E,s}$, and earthquake ground motion intensities $k_{E,u}$ and $k_{E,s}$ are determined as a function of a reference period and the probability of exceedance in the reference period. For a given probability of exceedance in a reference period a larger value of the earthquake ground motion intensity results in a smaller value of load factor and vice versa. It is to extent up to decision makers to choose a combination of the values of the load factor and the earthquake ground motion intensity. $\gamma_{E,u}$ and $\gamma_{E,s}$ are, as examples, listed in Tables 1 and 2 for a region of relatively high seismic hazard, along with the representative values of earthquake ground motion intensity $k_{E,u}$ and $k_{E,s}$. Return periods for the corresponding representative values are also shown, where the return period is defined as the expected time interval between which events greater than a certain magnitude are predicted to occur.

An example using the unity load factor for the normal consequence class of structures is shown in Table 1, and a common representative value k_E is used in Table 2.

Table 1 — Example 1 for load factors $\gamma_{E,u}$ and $\gamma_{E,s}$, and representative values $k_{E,u}$ and $k_{E,s}$ (where $k_{E,u} \neq k_{E,s}$, for normal soils in high seismic area)

Limit state	Consequence class	load factors $\gamma_{E,u}$ or $\gamma_{E,s}$	k_Z	$k_{E,u}$ or $k_{E,s}$	Return period for $k_{E,u}$ or $k_{E,s}$
Ultimate	a) High	1,5 to 2,0	1,0	0,4	500 years
	b) Normal	1,0			
	c) Low	0,4 to 0,8			
Serviceability	a) High	1,5 to 3,0	1,0	0,08	20 years
	b) Normal	1,0			
	c) Low	0,4 to 0,8			

Table 2 — Example 2 for load factors $\gamma_{E,u}$ and $\gamma_{E,s}$, and representative values k_E (for normal soils, in high seismic area)

Limit state	Consequence class	load factors $\gamma_{E,u}$ or $\gamma_{E,s}$	k_Z	$k_E = k_{E,u} = k_{E,s}$	Return period for k_E
Ultimate	a) High	3,0 to 4,0	1,0	0,2	100 years
	b) Normal	2,0			
	c) Low	0,8 to 1,6			
Serviceability	a) High	0,6 to 1,2			
	b) Normal	0,4			
	c) Low	0,16 to 0,32			

5.2 Soil factor

The soil factor k_S is usually described as the ratio of the peak acceleration (usually at the basement of structure) considering the effect of soil conditions to the peak ground acceleration for the reference site condition. It can be modelled as the function of k_Z $k_{E,u}$ or k_Z $k_{E,s}$ as well as that of the soil condition. Example values of k_S is tabulated in Table 3 considering the nonlinear characteristics of ground motion amplification. k_S is usually assumed to be constant and to be unity for high seismicity regions.

Table 3 — Example values of k_S

Soil condition	k_Z $k_{E,u}$ or k_Z $k_{E,s}$				
	< 0,1	0,2	0,3	0,4	> 0,5
Rock	1,0	1,0	1,0	1,0	1,0
Stiff soil	1,6	1,4	1,2	1,1	1,0
Soft soil	2,5	1,7	1,2	0,9	0,9

5.3 Structural design factor

The structural design factor k_D is used to reduce seismic forces computed for fixed-base linear elastic models to account for the beneficial effects of anticipated inelastic behaviour and foundation structure interaction, considering the structure's restoring force characteristics, ductility, damping, and overstrength.

The factor can be divided into two factors: namely $k_{D\mu}$ and k_{DS} and is expressed as the product of them as follows:

$$k_D = k_{D\mu}\, k_{Ds} \tag{5}$$

where, $k_{D\mu}$ is related to ductility, foundation structure interaction, restoring force characteristics, including damping, and the amount of damage considered acceptable at the ultimate limit state; and k_{DS} is related to overstrength. The structural design factor k_D with $k_{D\mu}$ may be for example, as Table 4.

Table 4 — Example of structural design factor $\boldsymbol{k_D}$ and $\boldsymbol{k_{D\mu}}$

Structural system with	$k_{D\mu}$	k_D
excellent ductility	1/5 to 1/3	1/12 to 1/6
medium ductility	1/3 to 1/2	1/6 to 1/3
poor ductility	1/2 to 1	1/3 to 1

The difference between $k_{D\mu}$ and k_D is mainly caused by the overstrength.
Calibration from the values in the table shows that k_{DS} is 1 to 2.

5.4 Normalized response spectrum

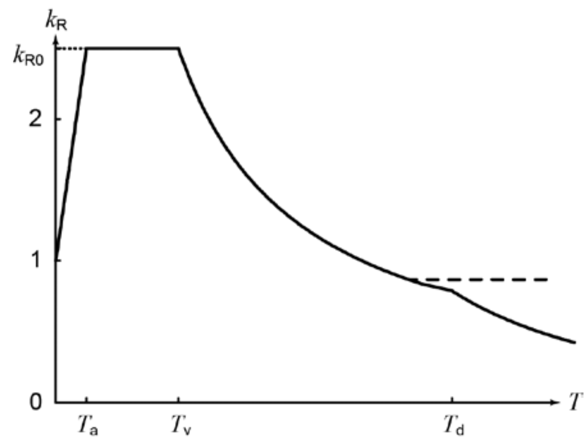
The normalized design response spectrum can be interpreted as an acceleration response spectrum normalized by the maximum ground acceleration for design purpose. It may be of the form in Fig. 1.

5.5 Seismic force distribution parameters

General characteristics of seismic force distribution parameters above the base are as follows.

a) For extremely stiff structures, whole parts from the top to the base move along with the ground motion. Then the distribution of seismic forces is uniform and the seismic shears increase linearly from the top to the base. This is called the uniform distribution of seismic forces (see the solid lines of Fig. 2). In Fig. 2, the normalized weight α_i (see Eq.(7)) is used as the ordinate, instead of height.

b) For low-rise buildings, the distribution of seismic forces becomes similar to the inverted triangle. Then the distribution of seismic shears is assumed to be a parabola whose vertex locates at the base. This is called the inverted triangular distribution of seismic forces (see the dashed lines of Fig.2).



Key

k_R Acceleration response spectrum normalized by the peak ground acceleration for design purpose

k_{R0} Ratio of the maximum acceleration response to the peak ground acceleration

T Fundamental natural period of the structure

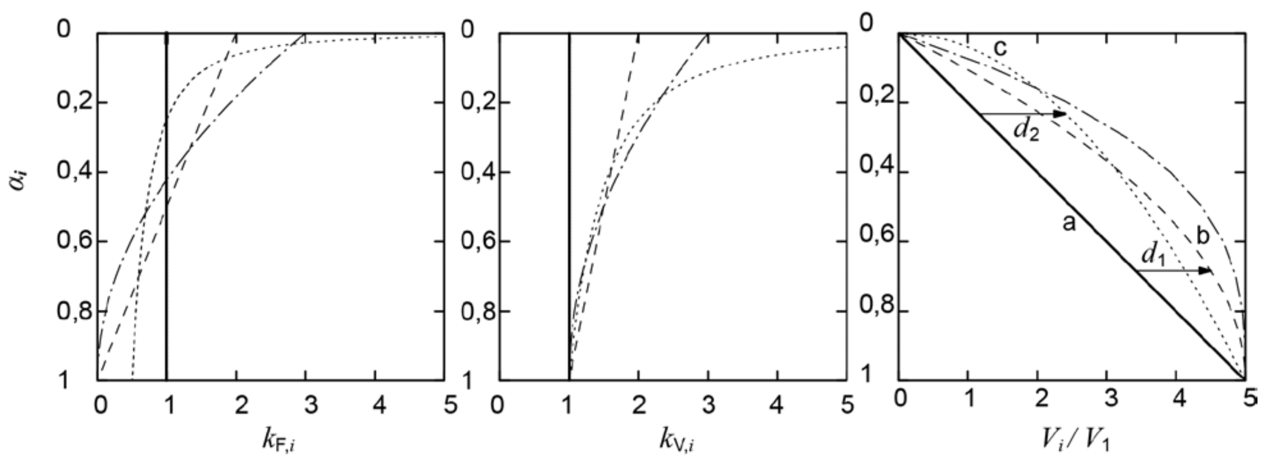
T_a, T_v, T_d Corner periods of the spectrum

.... k_R of short period structures for design

– – – – Lower limit for design

Fig. 1 — Normalized design spectrum

c) For high-rise buildings, seismic forces at the upper part become larger because of a higher mode effect. If the structure is assumed to be a uniform shear type elastic body fixed at the base and to be subjected to white noise excitation, the distribution of seismic shears becomes a parabola whose vertex locates at the top (see the dotted lines of Fig.2). This may be called the distribution for shear type structure subjected to white noise excitation or simply "$\sqrt{\alpha}$ distribution", because the shear distribution is proportional to $\sqrt{\alpha_i}$, where α_i is the normalized weight.



Key

α_i Normalized weight

$k_{F,i}$ Seismic force distribution factor

$k_{V,i}$ Seismic shear distribution factor

V_i / V_1 Normalized seismic shear

——— $k_1 = 0$, $k_2 = 0$ in Eq.(6)

- - - - - $k_1 = 1$, $k_2 = 0$ in Eq.(6)

.... $k_1 = 0$, $k_2 = 1$ in Eq.(6)

–·–·–·– Parabolic distribution of seismic forces

Fig. 2 — Seismic force distribution parameters

The above three types of normalized shear V_i / V_1 are given as follows:

a) For the uniform distribution of seismic forces (see the solid line “a” of Fig.2),

$$V_i / V_1 = \alpha_i$$

b) For the inverted triangular distribution of seismic forces (see the dashed line “b” of Fig.2),

$$V_i / V_1 = 1 - (1 - \alpha_i)^2 = 2\alpha_i - \alpha_1^{2}$$

c) For the $\sqrt{\alpha}$ distribution (see the dotted line “c” of Fig.2),

$$V_i / V_1 = \sqrt{\alpha_i}$$

The difference d_1 between “b” and “a” is given by $d_1 = \alpha_i - \alpha_i^2$, and the difference d_2 between “c” and “a” is $d_2 = \sqrt{\alpha_i} - \alpha_i$. Therefore, adjusting the factors k_1 and k_2, various types of the normalized shear distribution can be expressed as follows:

$$V_i / V_1 = \alpha_i + k_1 d_1 + k_2 d_2$$
$$= \alpha_i + k_1(\alpha_i - \alpha_1^{2}) + k_2(\sqrt{\alpha_i} - \alpha_i)$$

Dividing the above equation by α_i gives the seismic shear distribution factor $k_{V,i}$, that is the seismic shear factor of the i th level normalized by the base shear factor, as follows.

$$k_{V,i} = 1 + k_1(1 - \alpha_i) + k_2\left(\frac{1}{\sqrt{\alpha_i}} - 1\right) \tag{6}$$

where k_1 and k_2 are factors from 0 to 1 and are determined mainly by the height or the fundamental natural period of the structure, and α_i is the normalized weight that is given by

$$\alpha_i = \frac{\sum_{j=i}^{n} F_{G,j}}{\sum_{j=1}^{n} F_{G,j}} \tag{7}$$

The normalized weight α_i is used instead of the height h_i above the base, because the normalized weight is more convenient and rational to express distributions of seismic force parameters. Because of using α_i, various types of seismic force parameter can be compared as Fig.2.

In the case of a structure with uniform mass distribution, the normalized weight α_i may be approximated by the height h_i as follows:

$$\alpha_i \approx \frac{h_n - h_{i-1}}{h_n} \tag{8}$$

Distributions of seismic force parameters given by Eq.(6) are shown as solid lines in Fig.2 for $k_1 = 0$ and $k_2 = 0$ (uniform distribution of seismic forces), as dashed lines in Fig.2 for $k_1 = 1$ and $k_2 = 0$ (inverted triangular distribution of seismic forces), and as dotted lines in Fig.2 for $k_1 = 0$ and $k_2 = 1$ ($\sqrt{\alpha}$ distribution).

Therefore, the factor k_1 and k_2 may be taken as follows:

— $k_1 \approx 1$ and $k_2 \approx 0$ for low-rise buildings, or structures for which $T \leq 0{,}5$ s;

— $k_1 \approx 0{,}5$ and $k_2 \approx 0{,}5$ for mid-rise buildings, or structures for which $0{,}5 \text{ s} < T \leq 1{,}5$ s;

— $k_1 \approx 0$ and $k_2 \approx 1$ for high-rise buildings, or structures for which $T > 1,5$ s.

Incidentally, substituting $k_1 = k_2 = 2T / (1 + 3T)$, Eq.(6) becomes as follows.

$$k_{\mathrm{V},i} = 1 + \left(\frac{1}{\sqrt{\alpha_i}} - \alpha_i \right) \frac{2T}{1 + 3T} \tag{9}$$

This is denoted as A_i in the Japanese seismic code that has been used since 1981.

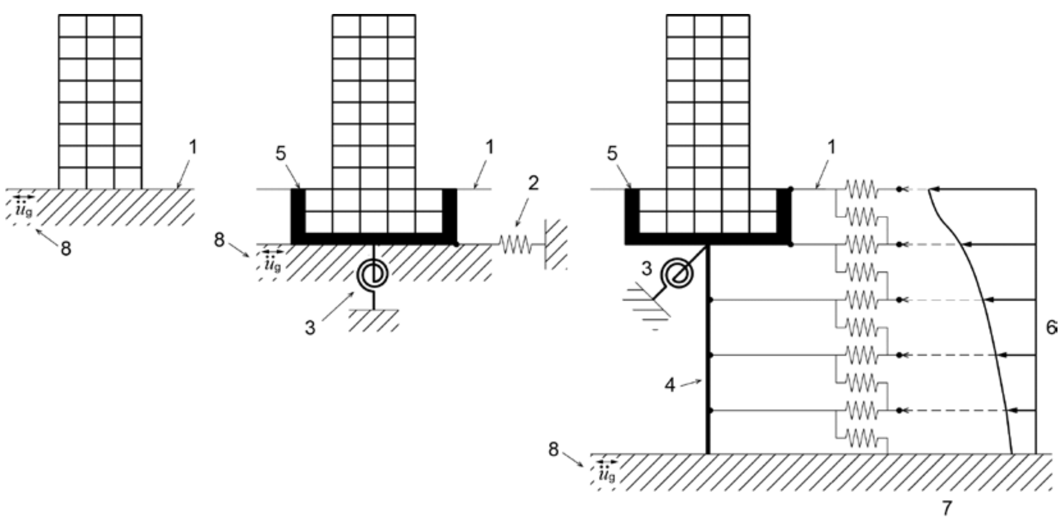
When the seismic actions for the parts of the structure projecting from the roof are evaluated, the seismic shear factor can be calculated by Eq.(6) assuming $k_1 \approx 0$ and $k_2 \approx 1$, and substituting the normalized weight of the part. Since the deformation caused by the earthquake ground motions concentrates at the level which has less stiffness, $k_{\mathrm{F},i}$ or $k_{\mathrm{V},j}$ should be adjusted to take account of such behaviour.

6. Annexes related to dynamic analysis, etc.

6.1 Dynamic analysis

Models of structure for dynamic analysis should include spatial representation of the mass as well as the dynamic characteristics of all elements intended to participate in resistance of earthquake forces. In general, sufficient degrees of freedom to capture significant response characteristics in three dimensions should be included. Planar models may be permitted only when torsional response can be demonstrated to be insignificant. In addition, if horizontal stiffness of a storey can be appropriately represented by a series of translational and rotational springs, one-dimensional lumped mass and spring models may be useful for simple but practical evaluation of seismic action.

Models may either be fixed at the base as illustrated in Fig.3a or represent the compliance of supporting soils with appropriate translational and/or rotational springs as illustrated in Fig.3b. More detailed soil-foundation-structure interaction models illustrated in Fig.3c are often used when earthquake motion is defined at the bedrock.



a) Fixed model b) Sway-rocking (SR) model c) Interaction model of structure with piles

Key
1. Ground level
2. Sway spring
3. Rocking spring
4. Piles
5. Foundation/basement
6. Forces caused by soil
7. Bedrock
8. Ground motion acceleration

Fig.3 — Examples of soil-structure interaction models

6.2 Deformation limits

There are two kinds of deformations to be controlled: the storey drift which is the lateral displacement within a storey and the total lateral displacement at some height relative to the base. The storey drift should be limited to restrict damage to nonstructural elements such as glass panels, curtain walls, plaster walls, and other partitions for moderate earthquake ground motions and to control failure of structural elements and the instability of the structure in the case of severe earthquake ground motions. Limits are frequently expressed in terms of the storey drift ratio, which is the storey drift divided by the storey height. In the evaluation of deformations under severe earthquake ground motions, it is generally necessary to account for the second order effect (P-delta effect) of additional moments due to gravity plus vertical seismic forces acting on the displaced structure which occurs as a result of severe earthquake ground motions.

For control of life threatening damage in occupied buildings at the ULS the storey drift ratio should be limited to values between 0,005 (1/200) to 0,025 (1/40), depending on the materials of construction, the height of the building, and the use of the building. An example tabulation of such effects is shown in Table 5. In other kinds of structures, limitations on storey drift may be governed by the drift capacity of nonstructural elements and systems. In critical facilities, the limits on storey drift ratio should be smaller as necessary to preserve function of the essential systems.

Table 5 — Example limiting storey drift ratios for buildings

	Normal consequence class	**High consequence class**
Low rise, without masonry	0,010 – 0,025 (1/100 – 1/40)	0,004 – 0,015 (1/250 – 1/67)
High rise, without masonry	0,005 – 0,020 (1/200 – 1/50)	0,002 – 0,010 (1/500 – 1/100)
With structural masonry	0,005 – 0,010 (1/200 – 1/100)	0,002 – 0,010 (1/500 – 1/100)

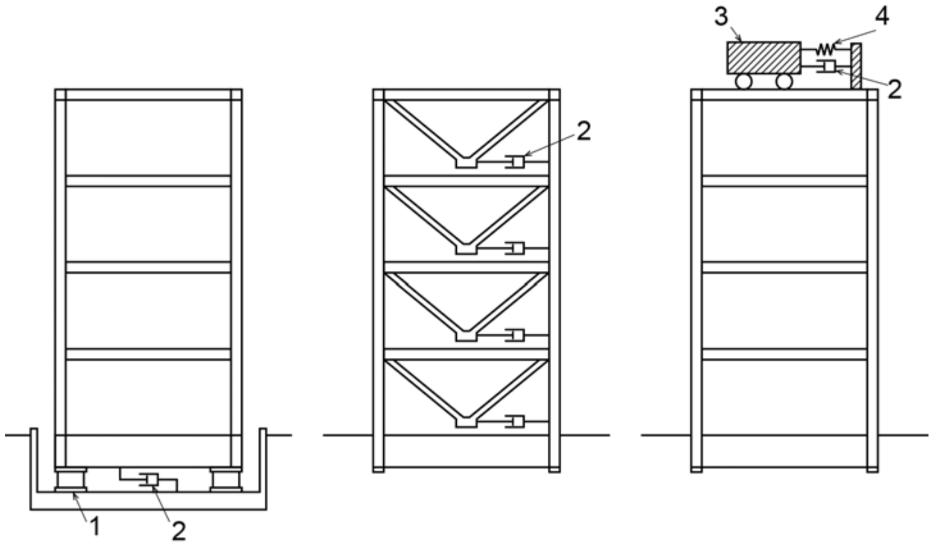
6.3 Response control systems

Recently response control systems (see Fig.4) including seismic isolation have been gradually applied to various structures, e.g. buildings, highway bridges and power plants and LNG tanks. The response control systems are utilized not only for new structures but also for existing structures to retrofit them. There are some response control systems to protect contents of structures, isolating the floors which support those contents, etc.

There are various types of response control systems, and some examples for the response control systems are illustrated in Fig.4. All systems except active (including partially active that is semi-active) control systems can be classified into passive control systems. The seismic isolation is to reduce the response of the structure by the isolators and dampers which are usually installed between the foundation and the structure. Since the isolators elongate the natural period of the structure and dampers increase damping, the acceleration response is reduced, but a large relative displacement occurs at the isolator installed storey.

6.4 Non-engineered construction

Many structures are spontaneously and informally constructed in various countries in the traditional manner with little or no intervention by qualified architects and/or engineers. Some types of non-engineered construction are (1) un-reinforced masonry (stone, brick or concrete block masonry), (2) confined masonry, (3) wooden construction, (4) earthen construction (adobe or tapial, i.e. rammed earth), etc. Many of these types of construction are unsatisfactory for use in seismically hazardous regions. Some of these types of construction can deliver satisfactory seismic performance given simple rules on basic layout, materials, and connections. Proper limitation on the size, height, and use (consequence class) of such empirically designed structures is essential.

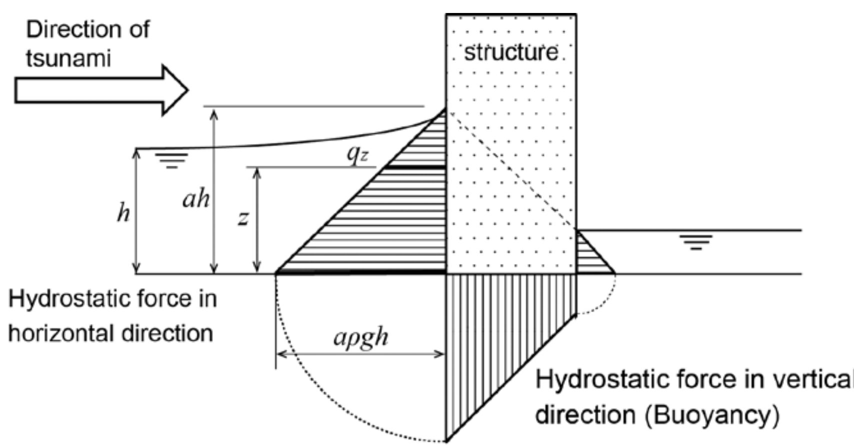


Key 1. Isolator, 2. Damper, 3. Mass, 4. Spring

Fig.4 — Example of passive control system

6.5 Tsunami actions

Damaging tsunamis are generally caused by large offshore earthquakes with moment magnitudes greater than $M_W7.5$ that induce significant vertical offsets in the sea floor. Tsunamis may inundate coastal regions several times during an event. Because tsunami waves have longer wavelength and have very low damping, they can travel great distances across oceans and still have considerable damaging energy particularly for coasts with unfavourable site configurations. Tsunamis may be also generated by a landslide in sea or lake, a mountain collapse, etc. Structures, that are located on land in tsunami hazard areas and required to withstand tsunamis, should be designed against tsunami actions (see Fig.5).



Key

a	Water depth factor	q_z	Hydrostatic pressure
g	Acceleration due to gravity	z	Height of the building at the level concerned
h	Design inundation depth	ρ	Density of sea water

Fig. 5 — Tsunami wave force on a structure

7. Conclusions

ISO/DIS 3010 for the third edition of ISO 3010 “Bases for design of structures - Seismic actions on structures” is under final review among member countries, and will be hopefully published as the International Standard by the end of 2016. The basic concept of the third edition remains the same as the first and second editions. However, it incorporates a new factor for equivalent static analysis, i.e. soil factor k_S. Several new annexes are included, i.e. H Non-linear static analysis and capacity spectrum method, J Soil-structure interaction, K Seismic design of high-rise buildings, L Deformation limits, N Non-engineered construction and O Tsunami actions. The third edition of ISO 3010 is expected to be used as a guideline for developing new national regulations or for revising existing national regulations of seismic design and loadings.

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